

**SYSTEM AND METHOD TO ENABLE WUSB APPLICATIONS IN A
DISTRIBUTED UWB MAC**

5 The present invention relates to a system and method for enabling wireless universal serial bus applications in a distributed ultra wide-band MAC.

 Universal serial bus (USB) technology is a popular and effective high-speed wired connection type for PCs that is migrating into the areas of consumer electronics (CE) and mobile devices. The next generation of USB technology is wireless USB (WUSB) and will
10 provide the functionality of wired USB without the inconvenience of wires and will be based on ultra wideband UWB radio.

 Referring now to FIG. 1, the typical or fundamental topology of WUSB is a hub-and-spoke-architecture comprising a host 101 and at least one connected device 102. In this architecture, all traffic 103 is initiated by the host 101 to its at least one connected device 102,
15 by allotting time slots and data bandwidth to each connected device 102.

 The relationship between a host 101 and its at least one connected device 102 is termed a cluster. The connections are point-to-point between a WUSB host 101 and its at least one connected WUSB device 102.

 A WUSB host 101 can logically connect to a maximum of 127 WUSB devices 102,
20 considered an informal WUSB cluster. WUSB clusters coexist within an overlapping spatial environment with minimum interference, thus allowing a number of other WUSB clusters to be present within the same radio cell.

 The WUSB architecture supports dual roles for a device 102 wherein a device 102 can also provide limited host capabilities. In this dual role model, such a device/host can
25 avail itself of the services of a central host 101 (i.e., printers) and can create a second cluster providing services itself as a host for accessing data outside any existing cluster it is connected to. This architecture supports high spatial capacity in small areas so that multiple devices have concurrent access to high bandwidth.

 In a wireless USB (WUSB) scenario there is one host 101 and one or more devices
30 102 that transmit data to the host. In the wired USB scenario the host sends a token or a poll frame to the devices to request data from the devices. It is expected that WUSB will use UWB MBOA MAC as a means to communicate between a host 101 and connected devices 102 over the wireless medium, see MBOA Wireless Medium Access Control (MAC) Specification For High Rate Wireless Personal Area Networks (WPANs), Technical

Specification, Draft 0.5, April 2004, which is hereby incorporated by reference as if fully set forth herein. Since the UWB MBOA MAC is distributed, there needs to be a method by which a host can reserve channel resources on behalf of connect devices 102 so that connected devices 102 can transmit data when requested by the host 101.

5 In the MBOA MAC specification the medium can be reserved by means of the “Distributed Reservation Protocol” (DRP). This protocol comprises two mechanisms of negotiating a reservation of channel time: an explicit negotiation by means of dedicated command frames, and an implicit negotiation by inclusion of the *DRP Information Elements* (IEs) in the beacon of sender and receiver’s. In both cases, once the reservation is established,
10 the reservation information is included in the beacon of sender as well as receiver(s) in every superframe, in which the reservation is still active. This is necessary in order to inform neighboring devices of sender and receiver(s) about the existing reservation. These neighboring devices have to store the reservation information received and abstain from medium access during the reserved period of time.

15 DRP reservations can be unicast or multicast reservations between two, respectively a group of devices.

 Thus, there is a need for a system and method for UWB MAC to reserve wireless channel resources so that connected devices 102 can send data to a host 101.

20 The present invention is based on a distributed UWB MBOA MAC that uses distributed reservation protocol (DRP) to exchange both isochronous and asynchronous data. That is, the present invention relates to data transfer between connected devices 102 and a host 101 that use the *DRP* protocol. The present invention provides a system and method for incorporating *DRP*-based host-device communication in wireless USB (WUSB).

25 In a first embodiment, the host 101 uses a multicast *DRP* (distributed reservation protocol) frame on behalf of connected devices 102 to reserve wireless channel resources for data transfer between the host 101 and connected devices 102 based on connected device characteristics and what traffic they have.

30 In the second embodiment the host 101 sends a unicast *DRP* frame to a connected device 102 and negotiates the use of channel resources for data transfer between the connected device 102 and the host 101.

 In a third embodiment the host 101 sends a *Poll* frame to a connected device 102 to trigger the transmission from said device 102.

 Thus, the present invention is a system and method for a distributed MAC protocol that provides a solution to incorporate WUSB data transfer therein.

Other features and advantages of the present invention will be obvious from the following drawings and detailed description of the invention.

FIG. 1 illustrates a typical hub-and-spoke WUSB architecture;

5 FIG. 2 illustrates a micro-scheduled DRP reservation according to the WUSB Working Group standard.

FIG. 3a illustrates an architecture of a host according to the present invention;

FIG. 3b illustrates an architecture of a connected device according to the present invention;

10 FIG. 4 illustrates a finite state diagram (FSD) for host data transfer processing.

It is to be understood by persons of ordinary skill in the art that the following descriptions are provided for purposes of illustration and not for limitation. An artisan understands that there are many variations that lie within the spirit of the invention and the scope of the appended claims. Unnecessary detail of known functions and operations may be omitted from the current description so as not to obscure the present invention.

The present invention provides a system and method for incorporating the host-device communication in wireless USB (WUSB). Referring now to FIG. 1, in a WUSB scenario there is one host 101 and one or more connected devices 102 that transmit data to the host 101. In the wired USB scenario the host sends a token or a poll frame to the devices to request data from the devices. WUSB could use UWB MBOA MAC as a means to communicate to other devices over the wireless medium. The UWB MBOA MAC is distributed and the present invention provides a system and a method by which a host 101 can reserve channel resources on behalf of connected devices 102 so that connected devices 102 can transmit data when requested by the host. That is, the present invention is a system and method for reserving wireless channel resources so that connected devices 102 can send data to a host 101.

In a first embodiment, a host 101 of a WUSB initiates a multicast DRP frame to reserve wireless channel resources with/on behalf of at least one WUSB device 102 connected thereto. Each of the at least one device 102 that is connected to the host 101 communicates device 102 characteristics to the host 101 that are used by the host 101 to reserve wireless channel capacity on behalf of the at least one device 102. One advantage of this embodiment is that the overhead of reservation is very low, since the multicast reservation is done for multiple devices. In addition, a combined reservation by the host results in there being only

one contiguous time period for the host 101 to receive data from the at least one device 102. In this first embodiment, the contiguous time period is scheduled for the at least one device using a protocol called micro-scheduling. The micro-scheduling protocol is defined in the “WUSB Key Developers, USB-IF, *WUSB Micro-scheduling Specification, Revision 0.5c*,
5 December 2003”, which is hereby incorporated by reference in its entirety and is illustrated in FIG 2. Micro-scheduling adds an efficient and extensible medium allocation mechanism for applications that require lower latency and finer grained bandwidth control. Under Micro-scheduling, the host reallocates the channel time within a DRP reservation on an intra-superframe basis. This allows the devices to rapidly and efficiently change the amount of
10 channel time allocated to other devices that are aware of and permitted to use the DRP reservation. The group using micro-scheduling is called a micro-scheduled cluster. The devices within the cluster that allocates the use of the medium within the micro-scheduled DRP reservation is called the Micro-Scheduled Cluster Controller (MSCC).

Thus, the multicast DRP protocol of the present invention is a way to incorporate into
15 UWB MAC the existing micro-scheduling scheme of the WUSB specification. The disadvantage of this scheme is that the host 101 must perform another multicast reservation or perform a unicast reservation for those devices 102 that did not agree with the initial multicast reservation.

In a second embodiment, the host 101 initiates a separate unicast DRP reservation to
20 the at least one device 102 to reserve channel resources. In this second embodiment, the number of reservation frames that need to be sent on the channel is directly proportional to the number of devices 102 connected to the host 101. This reservation initiation is equivalent to the micro-scheduled management command (MMC) of the current WUSB specification. Once the reservation is made, the host 101 uses a poll frame to request the at least one device
25 102 to transmit data during the reserved period. Advantages of the second embodiment include (1) it is a natural extension of DRP and (2) WUSB devices can be very simple. However, higher DRP negotiation overhead is incurred (depending on the number of WUSB devices). And, because DRP reservations may be spread through a superframe, this second embodiment may be less efficient than the micro-scheduling used by the first embodiment.

30 In a third embodiment, for WUSB transmissions that do not require DRP, the poll frame may also be sent by the host 101 using the EDCA channel access, that has control of the medium for a time specified by the EDCA TXOP limit, to request that the at least one device transmit data. The third embodiment has the advantage of flexibility and does not

require devices to support and implement DRP mechanisms. However, EDCA is a contention-based access and there are no guarantees against delays.

For each embodiment, the host 101 must know the capabilities of the at least one device 102. These capabilities are included by the at least one device 102 when the at least one device 102 transmits a Beacon. The host 101 also includes the host 101 capabilities in a Beacon. In each embodiment, the devices 102 announce if traffic is pending to the WUSB host 101. In each embodiment, WUSB device notification traffic can use a DRP reservation or device notification traffic can be sent using EDCA or using some signaling in the beacon frames.

WUSB host discovery is done via a Beacon in which the host includes its capabilities.

In order to achieve better packing and facilitate implementation, the Offset and Duration fields of a DRP reservation are preferably set to a multiple of "X", where X is selected based on the combination of the desired resolution of the DRP reservation and the size of the DRP slot. Typically, $X = 625\text{usec}$.

Referring now to FIG. 1, a typical WUSB network employs a hub-and-spoke architecture having a host 101 as the hub and at least one connected device 102 as a spoke. A typical WUSB host 101, according to the present invention, may include a host MAC module 300 with an architecture that is illustrated in the block diagram of FIG. 3a. A host 101 may include a host MAC module 300 having a controller 301 operatively coupled to at least a transmitter 302, a host data transfer processing component 303 comprising a host DRP processing module 303a and a host device notification processing module 303b according to the present invention, and a receiver 304. The transmitter 302 and the receiver 304 are operatively coupled to an antenna 305. The host DRP processing component 303a provides adaptive programming such that, for example, at least one of multicast and unicast DRP processing is accomplished by the host 101 for each connected device 102.

A typical WUSB connected device 102 may optionally include a more limited version of the host MAC module 300 as device MAC module 350 with an architecture that is illustrated in the block diagram of FIG. 3b. Each connected device 102 may include a device MAC module 350 having a controller 352 operatively coupled to at least a transmitter 302, a device processing component 353 comprising a device DRP processing module 353a and a device notification processing module 353b according to the present invention, and a receiver 304. The transmitter 302 and the receiver 304 are operatively coupled to an antenna 305. The device DRP processing component 353a provides adaptive programming such that, for example, at least one of multicast and unicast DRP processing is accomplished by the device

102 in response to reservations made by the host 101 and such that the connected device 102 further accepts or rejects a reservation made on its behalf by the host 101. In addition, if a connected device has additional capabilities for acting as a host itself, there is an optional device/host subcomponent (not shown), of each the modules 353a-b.

5 Referring now to FIG. 4, a finite state diagram (FSD) illustrates host data transfer processing 303 including DRP reservation functionality of the host DRP processing component 303a. Once the WUSB host is initialized 401, it starts beaconing 402 following the rules specified in the MBOA MAC. The beacon includes the WUSB host capabilities, so that WUSB devices can find the WUSB host by means of regular MAC beacon reception.
10 Once WUSB devices are initialized the devices follow the beaconing rules of the MBOA MAC, and look for the beacon from WUSB host(s).

The WUSB waits to receive the device notification traffic (DNT) via EDCA if DRP is not supported 403, or via EDCA or DRP if DRP is supported 405. Following the EDCA operation 403, once DNT traffic is received via EDCA, the WUSB host uses EDCA
15 mechanisms to access the medium and to poll the WUSB devices 406 according to a third embodiment of this invention. It should be noted that DNT traffic might be received via EDCA 403 even though the WUSB host supports DRP.

If DNT traffic is received and DRP is supported WUSB host initiates the DRP data negotiation process 405.

20 - If the WUSB host and devices support multicast DRP, the WUSB host includes a DRP multicast reservation in the beacon 408. Devices may adopt the reservation and include it in their own beacons. If all devices adopt the multicast reservation the WUSB host starts the micro-scheduling operation. If some devices do not adopt the multicast reservation, because, for example, they have a conflict with a
25 neighbor's reservation, the WUSB host may initiate a second WUSB multicast reservation or a unicast reservation with said devices 411. In a first embodiment of the invention the WUSB devices support at least the implicit DRP reservation mechanism. This requires the devices to listen to the beacons of other devices and to store the occupancy of all data slots during the superframe. This allows the
30 devices to eventually reject the multicast reservation request of the WUSB host and to eventually propose an alternative reservation time. In a second embodiment of the invention, the WUSB devices do not need to support the full DRP-functionality and just copy the DRP reservation information element from the beacon of the WUSB host into their own beacon.

- If WUSB host or devices do not support micro-scheduling during multicast DRP reservations, the WUSB host initiates a unicast DRP negotiation 407 and starts WUSB operation by using Poll Frames during the DRP reservations 409 according to another embodiment.

5 It should be appreciated that, to satisfy the requirements of devices with different capabilities, a combination of all mechanisms may be performed in parallel by the WUSB. Also it is possible that the WUSB host uses EDCA access to deliver traffic or to poll connected devices 406, even though a DRP reservation was established 409 410. This is useful for scenarios where there are interferences and channel errors and the time during the
10 DRP reservation cannot be used.

 While the preferred embodiments of the present invention have been illustrated and described, it will be understood by those skilled in the art that the superframe as described herein is illustrative and various changes and modifications may be made and equivalents may be substituted for elements thereof without departing from the true scope of the present
15 invention. In addition, many modifications may be made to adapt the teachings of the present invention to a particular situation without departing from its central scope. Therefore, it is intended that the present invention not be limited to the particular embodiments disclosed as the best mode contemplated for carrying out the present invention, but that the present invention include all embodiments falling within the scope of the appended claims.

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